Chapter - 5

DISCUSSION
Discussion

Tomato plant has been found susceptible to several virus in the natural conditions besides being susceptible to artificial infection by a number of virus (Vasudeva and Samraj, 1948; Nariani and Vasudeva, 1963; Sastry and Singh, 1971). A detail account of the naturally occurring and artificially transmitted tomato virus is now available. During 1983 to 2001 the disease caused frequent epiphytotics in Cuba, PuertoRico, Louisiana (U.S.A.) and Brazil which brought the sugar cane mosaic virus. In India the disease was first reported in the early of nineteenth century. The occurrence of mosaic disease of tomato was suspected in 1924 (Mc. Rac, 1924).

The disease of Tomato have been reported all over the world. These include mechanically transmissible virus disease of probable virus origin. Tomato mosaic mechanically and insect transmitted disease is one of these disease with world wide distribution.

Tomato (Lycopersicon esculentum) leaf curl caused by tobacco leaf curl virus (TLCV). The leaf of the plant affected by TLCV show a greenish yellow mottle and may be slightly curled and irregular in shape. TLCV often causes a
brown streaking of some of the branches. This cause yellowing and dropping of the leaf. At a time plant affected by this virus may show a general yellowing of many of leaves with little streaking of the stem. The common (green mottle) form of tobacco leaf curl often caused little leafy mottle symptoms on the fruit. However, fruit on streaked branches that have droppped many leaves often are yellow, and withered. One strain of this virus causes brilliant yellow, mottle of the leaves. It may also causes yellow spotting of some fruits. The spots are of irregular in shape and noticeable, as sunken and wrinkles. The virus is highly contagious and transmitted by mechanical means by contamination through implements, soil debris, clothes, hands of workers and touching of one plants with other. The TLCV is also transmitted through infected seed of tomato upto 22% . The host range in TLCV has got a very wide range.

Tomato leaf curl caused by Tobacco leaf curl (TLC) infected plants with the common form of TLC develop a mottling some what like that of TMV but with contrast between the light and often are abnormally narrow and pointed. Very few fruits are formed on infected plants and those produced sometime are miss happen and have dark green raised spots on the surface. Infected plant often are abnormally short and compact in appearance. At the time yellow rings are produced in the leaves and small fruits. These rings are a quarter half an inch in diameter on fruit and these are slightly sunken and concentric marking when both TMV and TLCV infected to the same plant, there is more yellow mottling of the foliage. The fruits also show more mottling.
Tomato leaf curl caused by TLCV is the disease characterized by severe leaf curl mottling, vein banding, mosaic and internal hypertrophy of the infected leaves. The midrib of the leaf is distorted and the leaves area is reduced considerably. The plants infected in the young stage show stunted growth. Fruits from diseased plant show chlorotic streaks and rough skin (Jeyarajan and Ramakrishnan, 1971). The virus is transmitted by sap to a number of herbaceous hosts and white fly vector. There are several white flies and *Aphids* vector of this virus in nature e.g. *Aphis craccivora*, *A. gossypii* and *A. evonymii* (Jeyarajan and Ramakrishnan, 1971).

Tomato leaf curl virus symptoms consists of abaxial and adaxial curling of the leaves accompanied by puckering and blistering of intervals areas and thickening and swelling of the vein as in advance disease. Axillary bud are stimulated to produce clusters of leaves which are reduced in size. The whole plant assumes bushy appearence with stunted growth of flowers and fruits and few are small, being curled at the end. The viruses are also transmitted through fly vectors. The insect vector is whitefly (*B. tabaci*). Host range of this disease have a very wide range. Important hosts are Tobacco, Capsicum, *Datura* and several weed strains. Two strains of virus are known, one producing enations under surface of the leaves and the other does not produced enations. The assessment of loss of the disease showed heavy loss in yield and quality of fruits. If the plant got infection within 20-25 days after transplanting the loss in yield goes upto 80-90%. However in case of later infection, the loss is
comparatively less.

Epidemiologically the disease spread more during summer months because summer months favour to white fly multiplication and disease spread. The virus persists on a several cultivated plants and weed host which serves as the source of inoculum.

During course of survey of virus tomato growing areas in eastern U.P., 21 tomato varieties were observed for the incidence of the mosaic and leaf curl disease. Ten varieties were found affected by the mosaic and leaf curl disease which include the following varieties, Pusa ruby, Pusa early dwarf, Money maker, Arca vikas, Selection-22, Navodaya, Morglobe, PKM-1, Punjab keshari and Punjab chuhara. It was observed that range of leaf curl disease incidence was highest in varieties Pusa ruby and Money maker. The incidence of mosaic range 10 - 50%. The maximum incidence was recorded in the month of June in the variety Money maker. The maximum incidence of tomato leaf curl during monsoon may be due to high white fly population, maximum rain fall, high humidity and medium temperature (26 to 28 °C) as reported by (Favi Vidaesky and Henryle Czoshek, 1998). However, high temperature low humidity and low rain fall and loss in white fly and vector population in May and June concluded with the decrease in the leaf curl incidence as found in the present investigation.

White fly are already reported for transmission of mosaic disease and insect contact in the secondary spread of tomato areas. In the present study maximum white fly population was reported during monsoon periods in and
around tomato cultivated fields which act as a vector and white fly tomato mosaic. The increase in vector population and aphid population during mansoon period along with high humidity may be one of the possible reason for the increase in the mosaic incidence of tomato in the month from March to June as has been observed in the present investigation.

Tomato plants from selected variety infected through various mechanical transmission methods. As presented in the tables of Chapter-4, the result clearly indicated that the combination methods of Bain's and Matz's was most successful including infection in the young tomato plants. It was also noted that, Bain's method for inoculating infection was more successful in the plants raised from seed than in those of plants raised through sets, which may be due to the tender nature of leaves of seedlings raised from true seeds in which virus could multiply more rapidly by causing more points of entry. The leaves if the plants through sets were not so tender and therefore, a combination of Bain's and Matz's methods of inoculation was more successful in this case.

Reduction in yield due to virus infection has been reported by several workers in various plants. Capoor (1952) and Nene (1972) reported reduction in yield of pigeon pea due to sterility tomato leaf curl virus. It was observed a big reduction in yield by early infection and losses by late infection in Cucurbita pepo infected with Water melon mosaic virus, Broad bean mosaic virus (Walter 1970) and in mung and urd bean due to mung yellow mosaic virus (Nene 1972).
Reduction in yield of the tomato plants under the present study has been found dependent on the time of inoculation, virulence of the isolated and vertical response to virus infection. High reduction in growth with ultimate great yield losses in the early virus infected crop has been observed. This might be a result of the effect of the attacked tissues or organ which has been found quite important in determining the host reaction with the virus infectivity. Matthews (1970) also confirmed the opinion that early infection could cause much severe reduction in the yield.

Reduction in chlorophyll contents with reduced rate of photosynthesis in tomato plants infected with tomato leaf curl virus has been noticed during the present investigation (Tu, et. al. 1968). This might be due to rapid virus replication which affects the yield by inducing change in the host physiology inducing reduced photosynthesis or enhanced respiration or both. The reduce growth of infected plants was mainly due to loss in photosynthesis rate in plant due to chlorophyll contents which ultimately caused the reduction in the yield of the crop.

In the present investigation diseased leaves had less area and reduced in number in comparison to healthy leaves. Similar to present findings, have been investigated by several workers. Stone (1936) found that diseased potato plants though they produced more leaves, the plant height increased more slowly and fresh weight per unit area was lesser than the normal plant. Chant (1960) while working with tobacco mosaic virus and cowpea yellow mosaic virus on cowpea
plant observed a significant reduction in the leaf area and number of leaves produced at every samplings, but the effect was considerably less with the tobacco mosaic virus and mean fresh weight of the leaf was significantly greater in healthy plants.


Although reduced growth of virus infected plant is the gross manifestation of disturbed metabolism, the direct cause of such reduction are mostly yet to be known (Bowden, 1964). The similarities between growth effects caused by virus infection and those produced by externally applied growth substances have led many workers to postulate that alteration in the and/or action of hormones, especially auxins may be the immediate reasons for growth disturbances in virus infected plants (Diener, 1963). This is supported by the findings of the several workers using different host viruses combinations (Grieve, 1936; Sooding and Funke, 1941; Pavillard, 1952 and Smith et al., 1960).

The reduction in the linear growth of shoot and root of tomato plants infected with TLCV in the present case seems due to the virus induced reduction in the amount of growth promoting substances or increase in the levels of growth inhibitors or both.

Comparatively little information is available about the effect of virus infection on root growth. It is, however, indicated that root growth is also
involved in the general growth reduction of virus infected plants (Bos, 1970). Reduction in root growth has been reported in clover infected with bean yellow mosaic virus (Smith and Gibsen, 1960), in *Dolichos lablab* infected with Dolichos enation mosaic virus (DEMV) (John, 1959; Rajagopalan and Raju, 1972), in rosette virus infected groundnut (Kousalaya *et al.*, 1970), in arhar (pea) mosaic virus infected sunnhemp plants (Singh and Mall, 1976b) and in common bean mosaic virus infected sunnhemp plants (Singh and Singh, 1979).

The reduction in relative growth rate (RGR; fig. IV.15) due to virus infection in the present case is in accordance to the findings of Bold and Hutton (1950).

Virus infection decreased net assimilation rate (Fig. IV.16) in several ways. Rolling and mottling of leaves may decrease the rate of photosynthesis by partial shadding of leaf surface. Thung, 1928; Watson and Watson, 1951, 1953 have supported similar findings in different host virus combinations.

The increase of leaf area ratio (Fig. IV.17) supports the findings of Watson and Watson, 1953. The increase in leaf area ratio may be due to great reduction in leaf area of TLCV infected Tomato plants.

The decrease in rate of relative leaf area increase (Fig. IV.14) may be also attributed to increase/decrease in leaf area which is associated with low rate of photosynthesis. The observations are also in accordance with the opinion expressed by Watson and Wilson (1956).
In the present investigation it has been observed that leaf, stem and root samples of diseased plants had always less moisture content and more dry matter content (Fig. IV.18-23). Moisture content of leaf, stem and root increased continuously with age of the plant in both healthy and diseased samples. Although there are many reports regarding altered water relations of plants infected with virus yet it is difficult to pin point these alterations.

Many workers have reported the effect of virus infection on moisture and dry matter content of plants infected with different viruses. Jodidi et al., (1920) reported increased dry matter content in blighted spinach plants. Carsner and Stahl (1924) observed increased dry matter content of sugarbeet leaves infected with curly top virus. Leaf roll affected potato leaves showed lesser moisture and higher dry matter content than healthy leaves (Campbell, 1925), Shapovalov and Jones (1930) observed an increase in dry matter in both leaf and stem of tomato plant infected with tomato yellow mosaic virus. In tomato leaves infected with tobacco mosaic virus decrease in water content was observed by Heuberger and Norton (1933) and Ainsworth and Selman (1936). Jeyarajan and Ramakrishnan (1971) and Dubey (1972) observed decreased moisture content in Chilli plants infected with potato virus Y and cucumber mosaic virus, respectively. Suteri (1974) also observed lesser moisture content in soybean mosaic virus. Gupta (1978) and Shukla (1978) has also reported less moisture content in plants. Singh and Singh (1978) have reported reduced moisture content in sunnhemp leaf, stem and root infected with common bean
mosaic virus.

In the present study TLCV infected Tomato plants had reduced moisture content. It may be either due to lack of assimilates or delayed nitrogen metabolism. The virus infected leaves mostly contained lesser starch and sugar as reported by Malhotra (1931), Rischkov, (1943), Gordon (1966), Khatri and Chenulu (1973) and Harman et al. (1970). Lesser sugar content has also recorded in diseased samples in the present study virus being nucleoprotein in nature, may diminish the growth by disturbing the normal nitrogen utilization of plant (Farrag and Ramakrishnan, 1969; Kapur and Wathers, 1971). The reduction in moisture content appears to be due to overall adverse effect of TLCV infection on metabolic system of diseased plants, as reported by many workers in virus infected plants (Diener, 1963).

The characteristic symptom of a mosaic type infection is the reduction in total green leaf area of the host. A loss in chlorophyll content due to virus infection in Tomato leaves was observed during the present study (Fig.IV.27). Similar results have been reported earlier by several workers (Dickson, 1922, Schweizer, 1926; Sorobin, 1926; Eular, 1930; Peterson, 1931; Esau, 1933; John, 1963a; Narayanaswamy and Ramakrishnan, 1965 a; Mandahar and Garg, 1972; Chaudhary and Mukhopadhyaya, 1974; Joshi and Dubey, 1975a; Singh et al., 1979; Shukla and Tiwari, 1985; Rao and Gupta, 1986). It was observed that mosaic symptoms were always exhibited only by the newly emerging leaves after inoculation with the virus. The inoculated leaves themselves or the other
already formed at the time of inoculation did not show the symptoms of the
disease. It may be due to the fact that the virus has no action on already formed
mature chloroplasts.

Generally the chlorophyll content in leaf increase with the age of plant.
Lal and De (1953) observed higher chlorophyll content in sugarcane leaves
from 45 to 90 days and then a gradual decrease in older plants. Higher pigment
concentration at this stage was attributed largely due to high magnesium and
protein content of leaves.

There are differences of opinion as to whether virus infection destroyed
the chlorophyll or inhibits its formation. Sheffield (1933) concluded that virus
of tomato aucuba mosaic did not effect the chlorophyll in leaves fully developed
at the time of infection but did prevent the formation of plastid in young-
growing leaves. On the other hand, some viruses such as those of cucumber
mosaic virus and tomato stripe produce chlorosis when rubbed over mature
leaves showing thereby that the already formed chlorophyll is destroyed. It is
possible that both may be true depending upon the time of infection and maturity
of leaves. Cook (1931) concluded that virus competes with the plastid for
some of the products necessary for their existence such as phosphorus and
nitrogen, but does not destroy them.

An increase in peroxidase activity has already been observed in the present
investigation (Fig. IV.28-30). The decrease in chlorophyll content may be partly
due to this increased peroxidase activity in the diseaaed plants. Opel (1965)
suggested that viruses induced chlorosis or necrosis which followed a chlorotic stage, could be explained as a deficiency of metabolites caused during the synthesis of virus. He attributed that the large amount of peroxidase in chlorotic tissue, to be due to the products of the breakdown of protein and chlorophyll (Singh et al., 2006).

Therefore, in the present study reduction in chlorophyll content of the Tomato leaves due to TLCV infection appears either due to destruction of the already formed chloroplasts or due to inhibition of its formation (Tripathi and Tewari, 2006).

Due to virus infection net production as well as gross production was reduced while the respiratory loss was increased (Fig.IV. 24-26) in comparison to their healthy counterparts. Similar reduction in primary productivity as a consequence of virus infection has been reported earlier (Bhargava, 1974, Gupta 1978, Singh et al., 1977 and Shukla, 1978, Tiwari and Shukla, 1985, Rao, 1986; Singh et al., 2007). Investigations with several viruses have show a reduction in photosynthetic activity in infected leaves which usually begins some dry wt. after infection (Owen, 1957 a, 1958 a and 1958 b; Jensen, 1968; Tu and Krass, 1968; Tu et al., 1968). The reduced photosynthesis, however, does not effect the dry weight per unit area. On the other hand, the dry weight of leaves on area basis increase conspicuously in the infected leaves as compare to healthy ones. This could be accounted for only if, there was a corresponding reduction in the rate of respiration resulting in increased net photosynthesis.
But in the present study accumulation of viral protein may be the cause of increased dry weight of infected leaves on unit area basis.

There have been other reports of virus induced increase in respiration (Bawden, 1959; Loebenstein and Linsey, 1966; Minke and Walker, 1963; Bell, 1964; Tu et al., 1968; Jensen, 1968 and Reddy and Chenulu, 1970). Singh and Singh (1978) while working with sunnhemp infected with common bean mosaic virus have also reported a reduced rate of net and gross production and an increased rate of respiratory loss.

The reduced rate of net photosynthesis and/or increased rate of respiratory loss appear to be the cause operative in the present case. The former will decrease the synthesis of carbohydrate and later would increase the synthesis of carbohydrate and later would increase its breakdown. The cumulative effect of the both would be to lower the carbohydrate level which ultimately effects the leaf productivity. A reduced capacity to synthesize the carbohydrate is characteristic of mosaic affected plants (Diener, 1963). The increase in respiration reduced content of chlorophyll in TLCV infected Tomato plant parts supports this view (Singh and Singh, 2007).

In the present study the highest peroxidase activity is observed in 75 day old plants samples (Fig. IV.28-30). The under present study express their visible symptoms within 10-15 days in Tomato plants.

There are several reports of increased peroxidase activity in virus infected plants by a number of workers. Suzuki (1902) observed increased peroxidase
activity in mulberry leaves infected with mulberry dwarf virus. Increased peroxidase activity was also observed in tomato and tobacco plants infected with tobacco mosaic virus (Chapman, 1913; Simons and Ross, 1970). Greater peroxidase activity in barley leaves affected by barley yellow dwarf virus was reported by Oriob and Arny (1961). Jeyarajan and Ramakrishnan (1968) reported increased peroxidase activity in potato virus Y affected chilli plants. Ramakrishnan et al., (1969) reported increased peroxidase activity in pigeon pea plant infected with pigeon pea sterility mosaic virus. Similar results were observed in sugarcane leaf, stem and root infected with sugarcane mosaic virus (Bhargava et al., 1970; Srivastava, 1971). Dubey (1972) recorded increased peroxidase activity in cucumber mosaic virus infected with chilli plants. Shukla and Tiwari (1985) also reported the increased peroxidase activity in watermelon mosaic virus infected with *Cucurbita maxima* plants.

The increased peroxidase activity as a consequence of virus infection has been reported in case of many host virus combination (Wynd, 1943; Gordon, 1966; Ambrosau and Schutskaya, 1973; Kapur et al., 1974; Joshi and Dubey, 1976; Suteri, 1974; Singh and Singh, 1979; Tripathi et al., 1975; Lele and Mukerji et al., 1980; Upadhyaya, 1981 and Singh, 1981; Vineeta et al., 2006).

Opel (1965) suggested that in virus infected plants the chlorotic stages attained as a result of deficiency of metabolites caused during the formation of virus. He also attributed that the breakdown of proteins and aminoacids caused an increase in peroxidase activity in chlorotic tissue.
A gradual increase in peroxidase enzyme activity in healthy plants with the age of the plants may be due to increase rate of cell formation and protein synthesis which requires such an elaborate system of enzymes, nucleic acids and ribosomes. The peroxidase enzyme has some role in lignin synthesis also (Bonner, 1950).

The flavoprotein enzymes, which produced \( \text{H}_2\text{O}_2 \) could be activated and higher level of peroxidase necessary for the oxidation of various substances by peroxidase could be one of the reasons for an increase in peroxidase activity. (Farakas and Kirlay, 1958).

According to Loebenstein and Linsey (1961) the high peroxidase activity in virus infected plant might be the consequence of the greater breakdown of carbohydrates through hexose monophosphate shunt. This cycle also produce precursors of the phenolic compounds which can be oxidised by peroxidase the quinones in the presence of \( \text{H}_2\text{O}_2 \) (Bonner, 1950).

Menke and Walker (1963) working with resistant and susceptible cucumber varieties infected with cucumber mosaic virus also observed increased peroxidase activity and found a close relationship of peroxidase, virus content and symptoms development. They observed that in their experiments the symptoms developed after 6-8 days of inoculation and at this stage, peroxidase had its highest increase over controls. Afterwards the activity remained more or less the same.

In the present study lower catalase activity was observed in leaves, stem
and roots of infected Tomato plants in comparison to healthy ones (Fig. IV.31-33). Such changes in catalase activity in virus infected plants have been reported by several workers (Chapman, 1913; Wynd, 1942; Hills and Mckinney 1942; Gimesi and Porsar, 1954; Vager, 1955; Narayanaswamy and Ramakrishnan, 1965; Singh, 1983). Gimesi and Porsar (1954) reported decreased catalase activity in plant infected with abutilon mosaic virus. Oriob and Arny (1961) reported decreased catalase activity in barley plant infected with barley yellow dwarf virus. Jeyarajan and Ramakrishnan (1968) in chilli plants infected with PVX and Bhargava et al., 1970; Srivastava, 1971 in sugarcane infected with sugarcane mosaic virus have also reported lesser catalase activity. Chilli plants infected with cucumber mosaic virus (Dubey, 1972) and in soybean mosaic virus affected soybean plants (Suteri, 1974; Singh and Singh 1978; Shukla and Tiwari, 1985).

In this study a general increase of polyphenoloxidase (PPO) activity in various plant parts has been observed throughout the experimental period in both healthy and infected samples, but PPO activity was found to be higher in infected plant parts than their comparable healthy ones. The highest percentage of increase was observed in 28th day samples (Fig. IV.34-36). This corresponded to the findings of Hampton and Fulton (1961); Venkaman and Bsouwer (1964); John and Weintraub (1967); Ambrosau and Schutakaya (1973) and Tripathi (1975).

Polyphenoloxidase catalyzes the oxidation of monophenols and diphenols
and aromatic amines to quinones in the presence of $\text{H}_2\text{O}_2$ (Bonner, 1950) and is possibly connected with the hexose monophosphate shunt pathway in which glucose 6-phosphate is dehydrogenated to 6-phosphate gluconate and other intermediates viz. ribose 5-phosphate or xylulose 5-phosphate (Loebeinstein and Linsey, 1961).

Polyphenol oxidase serves a terminal oxidase in infected plants tissues due to altered electron transport chain (Hare, 1966). This stimulates pentose phosphate pathways and the synthesis of precursors of phenolic compounds via the shikimic acid pathway, which in turn induce PPO synthesis in infected tissues (Kuc, 1986). Thus increase in phenolic content in infected samples cause increase in PPO activity.

Phenolases are also present in chloroplasts and a destruction of chloroplasts due to virus infection shown by the decrease in chlorophyllase activity induce the enzyme rapidly to a high level of activity (John and Weintraub, 1967).

The factors which affect the PPO activity (i.e., increase respiration and decreased chlorophyll) are more in TLCV infected plants than healthy ones. The increase may be due to the higher requirement of protein and enzymes for senescence.

Virus infection enhanced the nitrate reductase activity of Tomato plant parts in comparison with healthy plants. Activity of this enzyme in both healthy and virus infected plants was maximum in the leaves followed by stem and
roots (Fig. IV.37-39).

Increased nitrate reductase activity in virus infected plant parts has been also reported by Narayanaswamy and Ramakrishnan (1966 b) in pigeon pea sterility mosaic virus infected pigeon pea; Khatri and Chenulu (1973) in cowpea infected with cowpea mosaic virus. More nitrate reductase activity was reported in susceptible variety of cowpea infected with cowpea mosaic virus than its resistant variety (Khatri and Chenulu, 1973). Joshi and Prakash (1977) observed increased nitrate reductase activity in maize leaf infected with strain A and F of sugarcane mosaic virus. Shukla (1978) reported increased nitrate reductase activity in Sorghum leaf infected with Sorghum strains of SCMV, Singh and Singh (1982) reported increased nitrate reductase activity in cowpea plants infected with cowpea mosaic virus and Singh (1983) observed increased nitrate reductase activity in pumpkin plant infected with watermelon mosaic virus.

The higher activity of nitrate reductase in infected plant indicate enhanced rate of nitrogen assimilation, due to accelerated protein synthesis in virus infected plants.

Due to alteration in nitrogen status of virus infected plants it seems that most of the nitrate after absorption, is translocated in the leaves as such, where it is soon used up for active protein synthesis. This may be reason for the higher activity of the enzyme in the leaves than the other plant parts (Singh and Singh, 2008).

In the present study various carbohydrate fractions (reducing and non-
reducing sugar) studied show that the infection by TLCV the reducing sugars and non reducing sugar in the leaves, stem and roots of infected Tomato plants (Fig. IV.48-50). Such reduction in carbohydrate content has also been reported for various host virus combinations by several workers (Brewer et al., 1926; Bolas and Bowley, 1930; Bawden, 1964; Narayanaswamy and Ramakrishnan 1965, Singh and Mall, 1974; Singh et al., 1977, Singh and Singh, 1978; Naqvi et al., 1978; Kabi et al., 1979; Sindelar et al., 1980 and Upadhyaya, 1981, Shukla and Tiwari, 1985, Rao, 1986).

In a photosynthesis scheme given by Levitt (1969) there is a synthesis of amino acids and protein from intermediary products. The necessary carbon skeleton for such products are derived from the intermediary products.

It has been observed during the present study that the nitrogen content is greater in TLCV infected leaves than in healthy leaves (Fig. IV.49-54). Due to virus infection there is an increased demand for abnormal protein production required for the rapid synthesis of virus particles. For this purpose there has to be increased diversion of assimilated carbon towards protein synthesis resulting in the decreased production of carbohydrates.

The synthesis stages of photosynthesis is the anabolic counter parts of the respiration. It was noted that due to TLCV infection there was increase in the rate of respiration in the leaves (Fig. IV.24). Thus there was an increased breakdown of carbohydrate than in normal plants. The decrease is carbohydrate content in pigeon pea sterility mosaic virus affected plants was observed by
Narayanaswamy and Ramakrishnan (1965a) and explained it on the basis of possible retardation and faster breakdown of carbohydrate into amino acid which are ultimately used for protein synthesis. Reschkw (1943) also observed that in tobacco leaves affected with tobacco mosaic virus, accumulation of the virus coincided with the expenditure of carbohydrate and increased protein nitrogen and total nitrogen.

Diener (1963) reported that the decreased photosynthetic activity coupled with the increased respiratory rate generally observed in virus infected leaves, should lead to decreased concentration of assimilates i.e. carbohydrate.

Hence, it can be assumed that the reduced carbohydrate content reported in the present study may be very well due to reduced synthesis as well as increased utilization of sugar in infected plants.

In the present study the starch content in infected samples have been found to be present in lesser quantities (Fig.IV. 46-48). This may be either due to reduction in the rate of starch into sugars which after conversion into phosphohate esters serve as substrates for the enhanced rate of respiration. Jeyarajan and Ramakrishnan (1968) reported both the possibilities for the reduction of starch content in chilli leaves infected with potato virus Y. Similar results of decreased starch content in virus infected plants have been reported by many workers.

Dunlop (1931) reported reduction in starch content of tobacco leaves infected with tobacco mosaic virus. Malhotra (1931) observed lower percentage
of starch in infected potato leaves.

Narayanaswamy and Ramakrishnan (1965) observed that pigeon pea leaves affected by sterility mosaic disease had significantly less starch. Khatri and Chenulu (1969) also reported lesser starch in the infected leaves of cowpea infected with cowpea mosaic virus.

In the present study it was observed that nitrogen content of leaf, stem and root in infected plants was more than their healthy counterparts (Fig. IV.49-54). These findings are similar to Dunlap (1930) who suggested that mosaic type disease caused increase in the nitrogen content of infected plants.

Generally virus multiplication in plants results in the synthesis of abnormal protein in addition to plant proteins, results in overall increase of total nitrogen. Some workers, however, have reported decrease in total nitrogen in virus infected plants (Suzuki, 1902; Pantanelli, 1912; Jodidi et al., 1920; Rose, 1927; Wann and Blood, 1933; Riakhovsky and Feduleav, 1941; Elbertzhagen, 1958). Dunlap reported that mosaic disease were found to be accompanied by an increase of total nitrogen content in potato plants infected with potato mosaic virus. Similar observations were made by Cordingley et al., (1934) in virus infected tobacco plants. Stanley (1937) reported an increase in nitrogen content of tobacco leaves infected with tobacco mosaic virus and aucuba mosaic virus.

Increased total nitrogen have been reported by Cockerham (1937) in virus infected potato plants, Borges and Beato (1953) in turnip yellow virus infected Brassica chinensis leaves found increased nitrogen content. Porter
(1959) reported that tobacco virus caused a 'net increase' in serine, glutamine and aspartic acid in leaves of tobacco during early stages of infection. Selman et al. (1961) have also reported increase in amino acids and amides in leaves and stems of tomato plants infected with tomato spotted wilt virus. Doring and Wartenberg (1963) recorded the increase in total nitrogen in roots of potato plants infected with leaf roll virus.

Ford and Tu (1969) observed increase in ammonia and amide contents in corn infected with maize dwarf virus and with sugar cane mosaic virus. Later they also reported similar results in soybean leaves infected with soybean mosaic virus and bean pod mottle virus (Tu et al., 1970). Thankappan and Chacko (1970) have also reported the plant parts infected with virus and more amino acid and amides than corresponding parts of healthy plants of Cassava infected with Cassava mosaic virus. The accumulation was more in tubers than in leaves. Roots contained little amount of amino acids and amides. Srivastava (1971) and Dubey (1972) observed increased total nitrogen content in leaf, stem and root samples of mosaic infected sugarcane and cucumber mosaic virus infected chilli, respectively. Jeyarajan and Ramakrishanan (1972) reported increase in total nitrogen content of chilli plants infected with potato virus Y. Suteri (1974) and Gupta (1975) reported increased nitrogen content in leaf, stem and root of soybean infected with soybean mosaic virus respectively. Increase in total nitrogen content has been reported by many workers (John, 1973b; Narayanaswamy and Ramkrishanan, 1966 a; Harman et al., 1970; Khatri and

The main components of total nitrogen are probably insoluble proteins, free amino acids, amines, amides and inorganic phosphate. Alteration in any one of these components may disturb the nitrogen metabolism. A few viruses such as tobacco mosaic virus and potato virus X multiply to such an extent that virus protein contributes significantly to the total protein of the host and as a consequence there is an increase in total nitrogen. This might be one of the possibilities in the present case also. Martin et al., (1938, 39) have suggested that when a rapid virus multiplication takes place, protein synthesis as a whole is accelerated.

Commoner and Dietz (1952) working with tobacco mosaic virus on tobacco reported that virus synthesis was associated with a net increase in protein content. Results obtained in present study also support this contention.

In the present investigation it was observed that the infected leaf, stem and root samples had always more phenolic content than their comparable healthy counterparts. These results are similar to those of Jeyarajan and Ramakrishanan (1968); Melouk and Skotland (1970); and Naqvi et al. (1978).

The higher level of phenols in infected plant parts may be attribute to virus infection, as phenols have been reported to accumulate with almost every infection or mechanical damage and are implicated in the defence mechanism
of plants against diseases (Farkas and Kiraly, 1962).

The greater breakdown of carbohydrates through the hexosemono-phosphate shunt produces precursors of phenolic compounds which can be oxidized by peroxidase (Lobenstein and Linsey, 1961). In the present study an increased content of phenolics, in infected plants support the view.

The increase in phenolic content may be due to its enhanced biosynthesis as an increased aromatic biosynthesis is characteristic of all injured or infected tissues (Ghabrial and Pirone, 1967). The virus infection stimulates erythrose phosphate and phosphoenol pyruvate synthesis, thus increasing the phenol content. The loss of regulatory properties of allosteric enzymes involved in the biosynthesis might be a reason for increased accumulation of phenolic compounds in diseased plant tissues (Kosuge, 1969).